

Analysis of Train Derailment in Collision with a Road-Rail Vehicle in the Station Yard of Kawasaki Station



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Abstract

A deadhead train collided with road-rail vehicle at Kawasaki station on the Keihin-Tohoku line in 2014, resulting in the 1st car being damaged and the 1st and 2nd car overturning. Damage was severe, even though the lead car of the train was designed to absorb the impact of a collision with a dump truck at a level crossing. We therefore investigated the cause of the damage by inferring the situation from collision to overturning from traces found on the train cars, road-rail vehicle, and track. From that, we studied improvements that could be made to safety in collisions similar to this accident.

●**Keywords:** Crashworthiness, Derailment, Road-rail vehicle, Train protection radio

1. Introduction

At 1:11 a.m. on February 23, 2014 (Sun.), the driver of a Keihin-Tohoku Line deadhead train consisting of ten series E233 EMU cars found a road-rail type construction carrier vehicle (hereinafter, the “road-rail vehicle”) approx. 100 m ahead while cruising in the station yard at approx. 65 km/h. He immediately applied the emergency brake; however, the train collided with the road-rail vehicle, causing derailment of the lead car (car No. 10) and the second car (car No.9). The train halted with the lead car overturned left of the direction of travel and the second car at an approx. 45° angle left of the direction of travel (Fig. 1).¹⁾

As a measure against collision with a dump truck at a level crossing (Fig. 2),²⁾ the lead car that collided with the road-rail vehicle was designed to have a crushable zone that would intentionally deform to absorb impact energy and a survival zone that would reduce deformation in order to protect the crew as well as a shock absorbing coupler between that car and the second car.³⁾ Nevertheless, the collision severely damaged the front and the underframe of the lead car, and the survival zone was greatly deformed while the crushable zone was not deformed much (Fig.3). On top of that, the car overturned.

In this study, we inferred the positions of the cars and road-rail vehicle relative to each other at the collision and the process by which individual parts of cars were damaged and the lead car overturned based on the damage to the train cars and road-rail vehicle, traces seen on the track, and the data of onboard devices. We furthermore studied improvements that could be made to safety in conditions different from those of a collision with a dump truck.

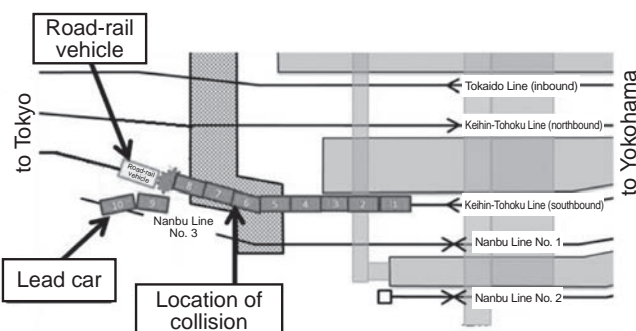


Fig. 1 Plan of the Yard of Kawasaki Station

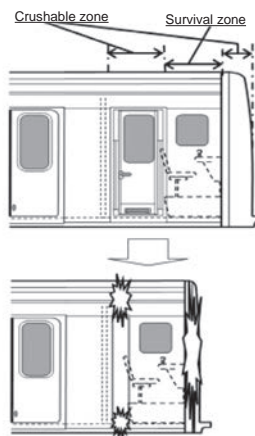


Fig. 2 Measures Against Collisions

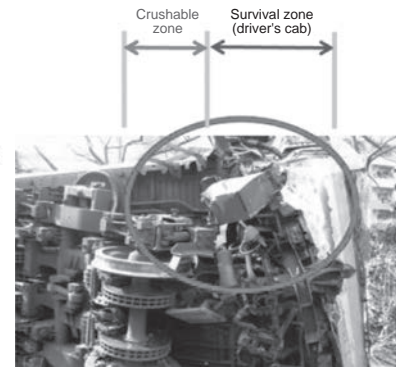


Fig. 3 Damage to Lead Car

2. Investigation of Cars and Road-Rail Vehicle

2.1 Inference of Behavior of Lead Car and Road-Rail Vehicle at the Collision

In order to identify the positions of the lead car and road-rail vehicle relative to each other at the collision, we inferred the relative angle between the car and the road-rail vehicle (Fig. 4-2) from traces on the car (Fig. 4-1) and track and damage to the underframe of the lead car. Our conclusion is that the lead car collided with the road-rail vehicle at an angle of approx. 6° with an offset of 70 mm between the ends of centerlines of the lead car and the road-rail vehicle (Fig. 4-3, 4).

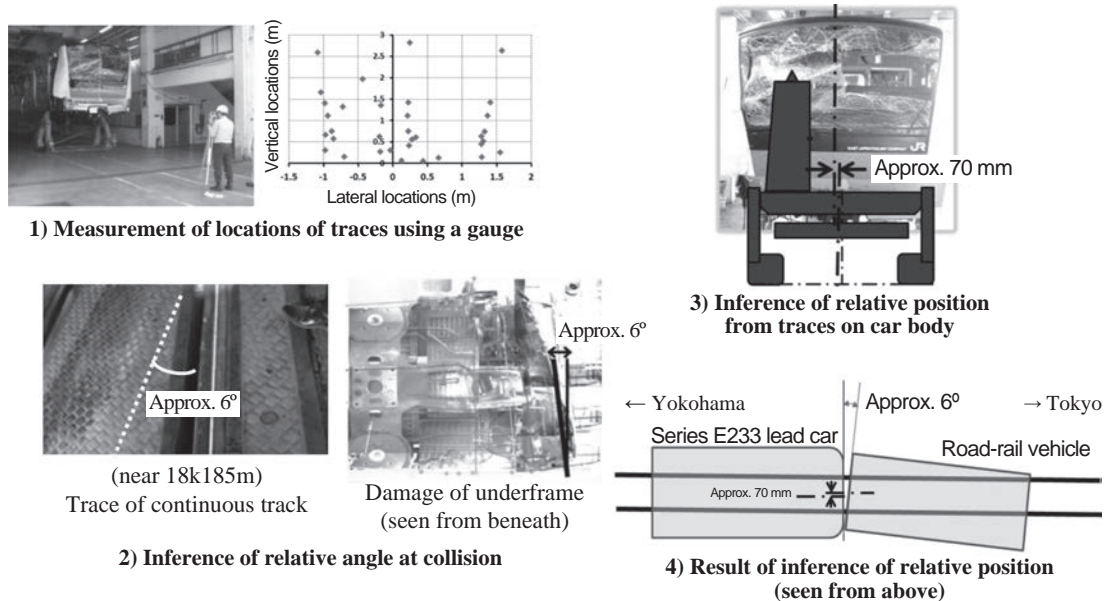


Fig. 4 Inference of Relative Position at Collision

The positions of the lead car and the road-rail vehicle relative to each other (Fig. 4) suggest the process by which the front of the lead car was severely damaged on the right side in the direction of travel (Fig. 3) is as follows. First, the end beam of the lead car impacted the road-rail vehicle at a position inside of the side beam (Fig. 5-1). The collision caused damage to the corner post of the car (Fig. 5-2) and consequently buckled the side beam of the lead car outward. In such a collision, impact energy conveyed to the crushable zone behind the end beam should have deformed that zone; however, the buckled side beam probably deformed the survival zone instead of the crushable zone in this collision.

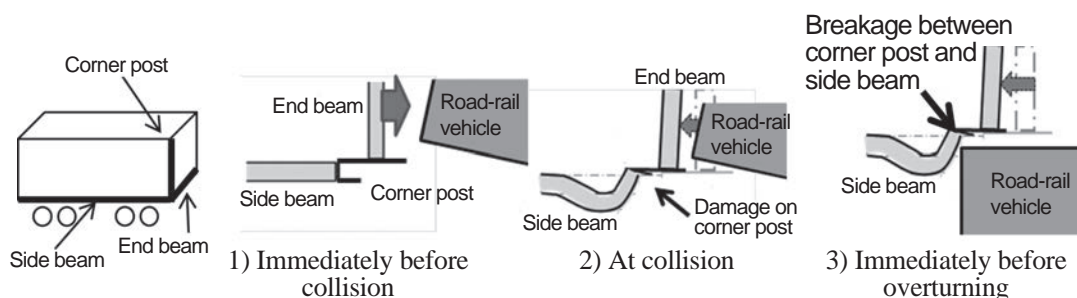


Fig. 5 Lead Car Damage by Collision

2.2 Inference of Behavior of Car

Damage to the track suggests that the process from collision up to overturning of the lead car was as follows. The road-rail vehicle was located on the right side of the train in the direction of travel as shown in Fig. 6. The buckled side beam of the lead car (Fig. 5-3) propelled the road-rail vehicle along the track, and subsequently, an outrigger of that vehicle hit a set-off device placed on the right side of the track. The travel of the road-rail vehicle was blocked and that lifted the rear part of that vehicle and the front of the lead car, causing the car to overturn at the same time. It is inferred that, due to breakage of the car body between the corner post and the side beam, the road-rail vehicle impacted the side of the lead car that began overturning.

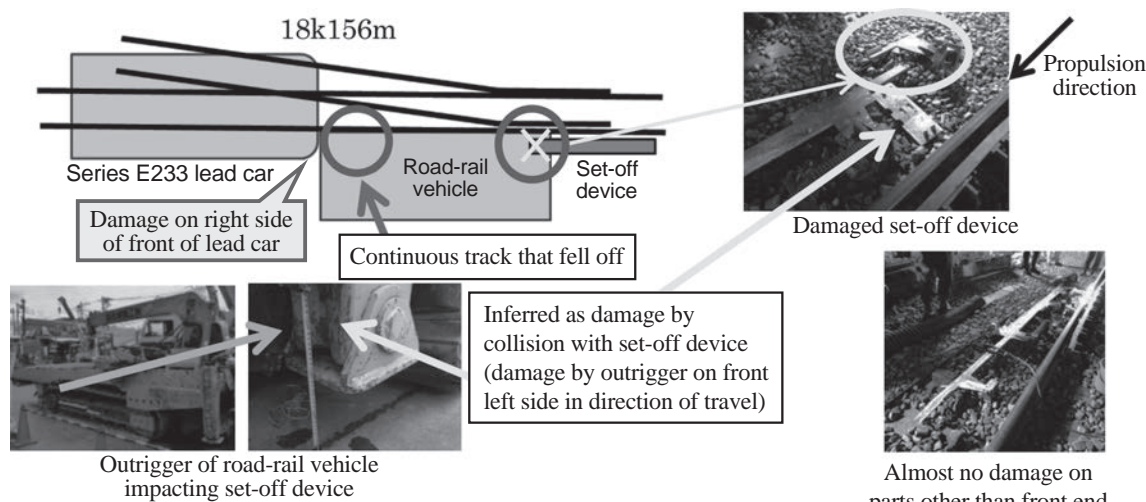


Fig. 6 Inference of Situation Immediately before Collision

2.3 Verification Using Data Recorded by Onboard Devices (Fig. 7)

We verified whether the aforementioned inference agreed with the acceleration waveform at the collision recorded by the system for automatic transmission of train protection radio signals⁴⁾ and the velocity and kilometrage of the operation information recorder. The system for automatic transmission of train protection radio signals recorded vertical, longitudinal, and lateral acceleration at and around the collision, and the records showed that the first impact was 6.6 G (65 m/s²) and then the second and following cars impacted in series with the maximum acceleration being 8.7 G (85 m/s²) at the impact of the third car, which is less than the design target of 10 G (98 m/s²). We were able to confirm that activation of shock absorbing couplers controlled the impact of the second car, demonstrating that maximum acceleration was reduced by shock absorbing couplers. Since overturning of the lead car started after longitudinal impact at the position where the road-rail vehicle seemed to impact the set-off device, we could conclude that the inference in the previous paragraph agreed with the recorded data.

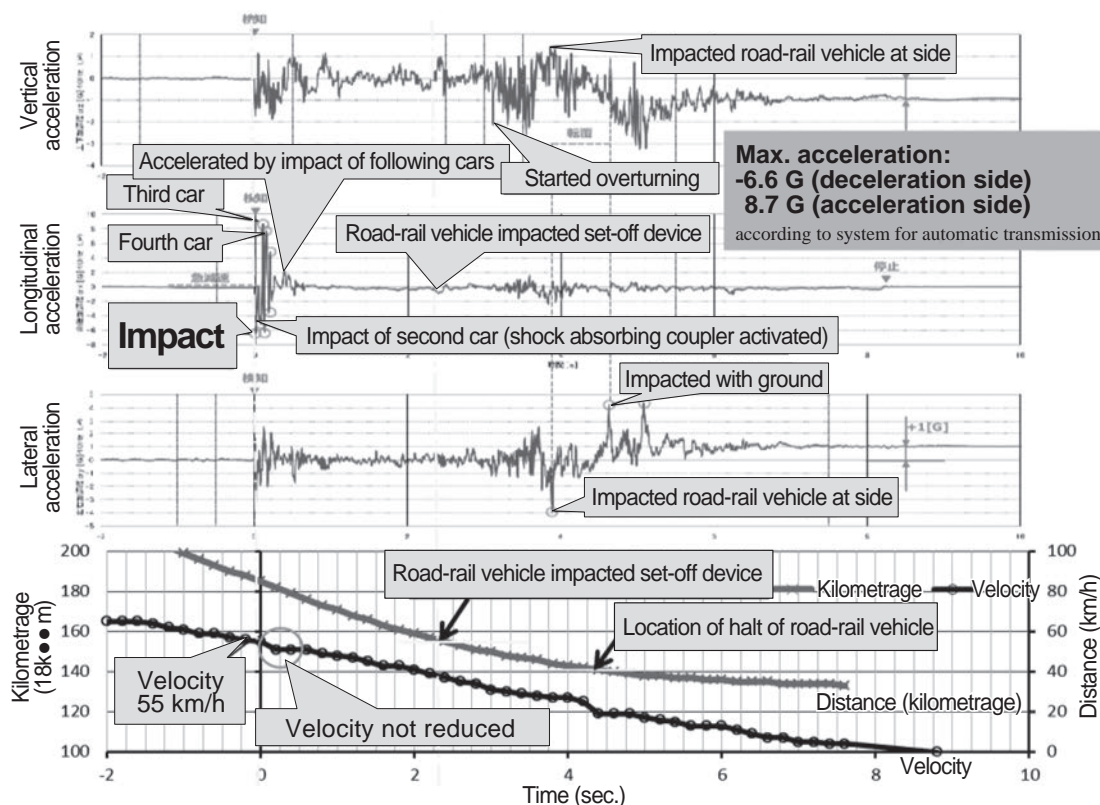


Fig. 7 Verification Using Records of System for Automatic Transmission of Train Protection Radio Signals and Operation Information Recorder

2.4 Investigation of Damage of Individual Cars of the Trainset (Fig. 8)

Investigating damage of individual cars of the trainset, we found that follower plates of the couplers of the first and second cars were deformed by impact and then fell off. Impact traces on the single links of the bogies suggest that buckling occurred as shown in Fig. 8 and damage on the lower yoke bearings of the first to fifth cars (No. 10 to 6) indicates that tilting of couplers caused major impact on those bearings. Such deformation and loss of a lower yoke bearing is often observed in buckling. Damage of a coupler including loss of a follower plate and a draft gear lower yoke bearing could cause impact of cars, resulting in greater damage.

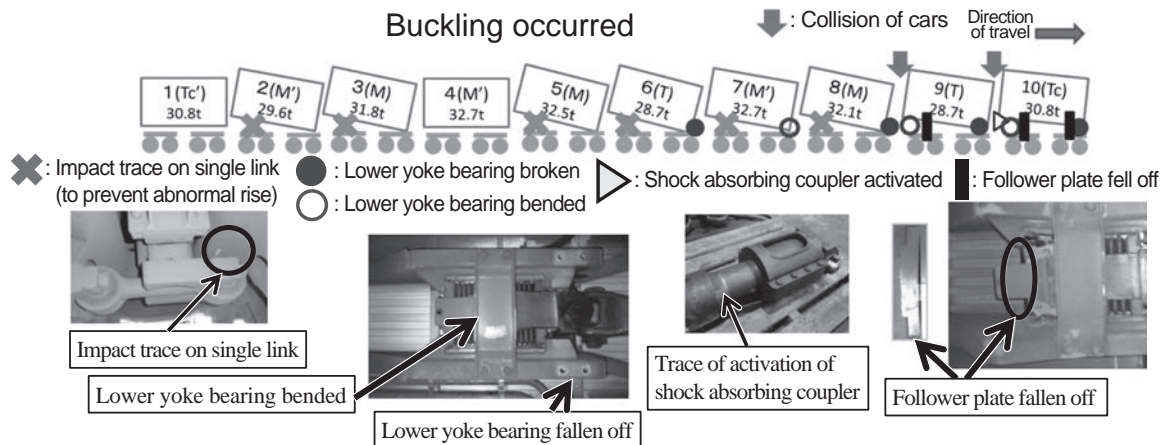


Fig. 8 Damage to Trainset

3. Conclusion

From the analysis results of this collision, we concluded that following two improvements would achieve higher collision safety.

- (1) Reinforce the car body between end beam and side beam in order to achieve car body structure that can convey impact energy on and around end beam to crushable zone.
- (2) Absorb impact energy and thereby abate damage by improving balance of strength between lower yoke bearing, follower plate, and car body frame in order to allow the underframe to deform.

Based on the investigations of past level crossing accidents, we have designed a shock absorbing structure for lead cars to secure a survival space and to alleviate impact on the human body for maximum collision safety for passengers and crew. In order to further improve collision safety, we intend to analyze and study damage and behavior of train cars in actual collisions in more detail.

Reference:

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